The effects of caffeine on linked food webs via chemical diffusing substrata

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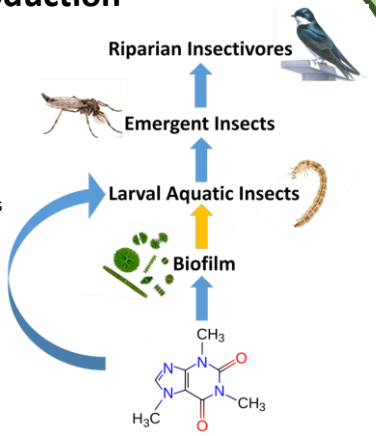
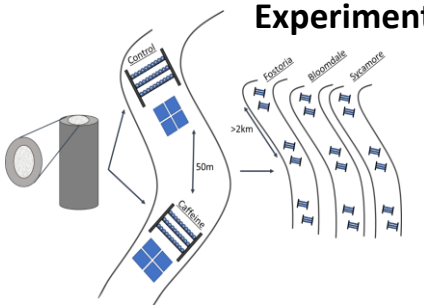
Introduction

- Caffeine is a commonly found aquatic contaminant
- Has been shown to have various effects on macroinvertebrates (Mustard, 2014)
  - Increased activity rates
  - Increased mortality rates
- Aquatic and neighboring riparian food webs are linked by subsidies (Baxter et. al., 2005)
- Emergent insects are hatched underwater but then leave streams to riparian zone
- Part of both aquatic and riparian food webs (Paetzold et. al., 2005)

- **What are the direct and indirect (via food source) effects of caffeine on linked food webs?**



Experimental Design



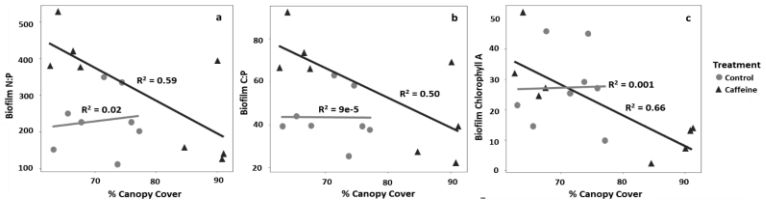
- Three stretches of stream with three pairs of control and caffeine experimental setups
  - Caffeine sites located ~50m downstream of control sites
- Sample sites were chosen because of known low caffeine concentrations
- Bathroom tiles were used to grow stream biofilm (common food source for benthic macroinvertebrates)
- Each site had a CDS unit, bathroom tile for biofilm growth, and a trap for emergent insects

Methods

- High concentrations of caffeine were added to streams via CDS (caffeine diffusing substrata). These CDS consisted of 50mL plastic containers filled with caffeine-infused nutrient agar. A hole was drilled in the lid and covered with a sponge to allow the agar to diffuse into the stream water.

- CDS were destroyed probably by mink and were reconstructed inside of dog crates to prevent further tampering
- Instream measurements: caffeine concentrations, PO_4, NO_2NO_3, % Canopy Cover, NH_3
- Biofilm measurements: Chlorophyll a, N:P, C:N, C:P
- Benthic macroinvertebrates sampled via kicknet just downstream of CDS
- Benthic and emergent macroinvertebrates identified to order

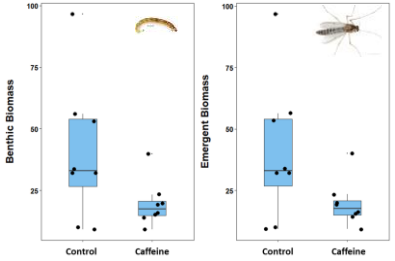
Results

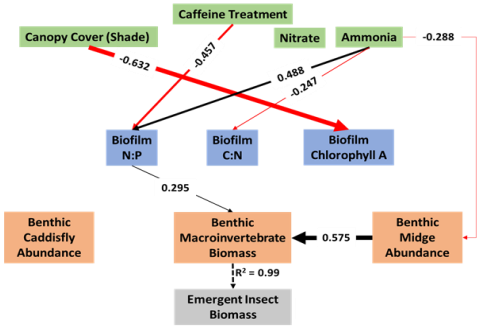


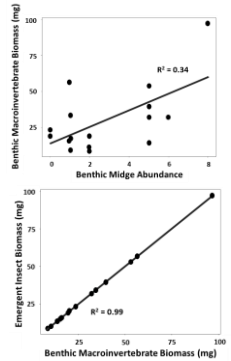
- Biofilm N:P, C:P, and Chlorophyll a significantly increased with the addition of caffeine but only under low canopy cover conditions
  - Phosphorus content decreasing in stream biofilm may decrease the nutritional value to benthic consumers
  - This is an indirect effect of caffeine on benthic macroinvertebrate biomass as well as emergent insects

Results and Conclusions

- Significantly lower benthic and emergent macroinvertebrates at caffeine locations than at control locations
- Most affected taxa were caddisflies (Trichoptera) and midges (Diptera)
- Canopy Cover (light availability) was found to have an interactive relationship with caffeine







- Structural Equation Modeling (SEM) indicated significant ($p<0.05$) effects of caffeine on macroinvertebrates ($\chi^2 = 20.479$, df = 15, N = 16, p = 0.154). Note that emergent insect biomass could not be included in the model due to the strong relationship with benthic biomass ($R^2 = 0.99$)
- The above graphical representation includes arrows of varying size denoting effect size along with standardized coefficients for each path.

Within this study, caffeine does negatively affect benthic macroinvertebrate biomass and emergent insect biomass. Although the mechanisms remain unclear, we can conclude that the effects caffeine, as an aquatic contaminant, are not restricted to stream food webs but cascade into riparian food webs (Marshall et. al., 2021).

References

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